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COMPARISON OF WOOD STORK FORAGING SUCCESS AND BEHAVIOR IN SELECTED TIDAL AND NON-TIDAL HABITATS

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ABSTRACT.—In 1999, we compared foraging success rates (captures/min) and foraging behaviors of Wood Storks (*Mycteria americana*) at tidal (Georgia) and non-tidal freshwater (South Carolina) foraging sites. Foraging success rates were 30 times greater at the tidal site, but storks foraging in tidal areas only fed at low tide, which limited their foraging time at that site. On-site behaviors indicated the window of prey availability. Storks at the tidal site engaged almost exclusively in foraging behaviors, whereas storks at the non-tidal site devoted more time to other, non-foraging behaviors (e.g., preening, resting). The greater foraging success rate associated with the tidal site suggests that salt marsh/tidal creek habitats are high-quality foraging areas. *Received 21 December 2004, accepted 6 September 2005.*

Wading birds use a diversity of behaviors to acquire prey. Wood Storks (*Mycteria americana*) feed mostly by tactilocation, literally bumping into their prey with partially open bills and capturing prey with a rapid reflex action (Kahl and Peacock 1963). They also employ a repertoire of associated behaviors (e.g., foot stirring, wing flashing) for startling prey or otherwise making them more active and possibly more catchable (Kushlan 1978).

To forage effectively, Wood Storks require shallow wetlands with concentrations of prey (Kahl 1964). Non-tidal freshwater foraging habitats in Georgia are typically shallow, relatively free of vegetation, non-flowing, and support prey densities ranging from 0.1 to 50.0 prey items/m^2 (mean = 7.8 prey/m^2; Coulter and Bryan 1993). The use of tidal salt marshes by foraging storks has also been documented during both breeding and nonbreeding seasons, and it is presumed that tidal creeks draining as the tide recedes (2.5 m tidal amplitude in Georgia) provide excellent conditions for foraging storks (Gaines et al. 1998, Bryan et al. 2002). To test this presumption, we observed storks within tidal and freshwater non-tidal foraging habitats in 1999 to compare foraging success rates and behaviors. The Wood Stork was federally listed as an endangered species in 1984 due to population declines resulting from loss of their shallow wetland foraging habitats (U.S. Fish and Wildlife Service 1986, 1996). Determining the type and quality of foraging habitat is an important step toward the recovery of this species.

METHODS

Study areas and behavioral observations.—We studied Wood Stork foraging behavior in salt marsh (tidal site) and freshwater (non-tidal site) systems. The 180-ha Purvis Creek salt marsh (tidal site) is located on the western edge of the Brunswick peninsula in Camden County, Georgia (31° 11′ N, 81° 31′ W). We conducted observations during daylight hours between 6 July and 24 September 1999. The storks included in our observations were nonbreeding (postbreeding season) birds. Wood Storks typically forage in the tidal creeks of salt marshes at low tide (Gaines et al. 1998); therefore, we limited our observations to 2 hr before and after dead low tide in tidal creek habitat. We conducted behavioral observations from a camouflaged boat temporarily anchored in an area used by storks. The boat was positioned during high tide and became stranded on the mudflats during our low tide observations. We recorded behaviors of focal storks with a Panasonic VHF video camera. One person (CSE) reviewed all VHF tapes and documented stork behaviors.

We observed foraging storks at a non-tidal freshwater site at the Kathwood ponds in south-central (Aiken County) South Carolina (33° 20′ N, 81° 50′ W). These 16 ha of freshwater impoundments were established in 1986 and stocked with fish to provide foraging hab-

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itat for storks during the postbreeding season. Coulter et al. (1987) and Bryan et al. (2000) provide detailed descriptions of impoundment management activities. We conducted our observations of storks during crepuscular and daylight hours of July and August 1999, when the impoundments were partially drained to mimic the natural drawdown of freshwater systems. Prey densities in the partially drained impoundments were high relative to natural foraging sites (densities ranged from 10 to 30/m^2; Bryan et al. 2001). At Kathwood, we used binoculars and spotting scopes to observe storks from a 2-m-tall blind placed at the edge of the impoundments.

We conducted continuous sampling of focal storks (Altmann 1974), which allowed us to calculate time budgets of both foraging and non-foraging behaviors for individual birds. Birds were observed for a minimum of 5 min (Walsh 1990), although longer observations were attempted. Focal storks were observed until they disappeared from view (departed from the site, moved behind an obstruction, or could no longer be distinguished from other storks), at which point we switched to a different focal stork. We recorded the following behaviors while the focal bird was actively foraging: foraging success (captures/min), locomotion patterns (walking with bill out of water, flushing/flying, or standing still), limb movements (foot stirring and wing flashing to enhance foraging), interactions with other birds on the foraging site (aggression), and other general behaviors. We categorized foraging as successful when the focal bird snapped its bill in the water, then raised its bill out of the water (prey were often observed) and tilted its head back as if swallowing. Possible unsuccessful foraging attempts (e.g., bill snapping in the water without subsequently raising the bill) could not be determined with certainty given field conditions (distance and lighting). Stork age (adult, subadult, hatch-year) was determined by plumage characteristics (Coulter et al. 1999).

Data analysis.—Specific behaviors during each observation were calculated both on a per-minute basis and as percentages of the total observation period for that bird. We used Wilcoxon rank-sum tests to compare foraging success rates and observation duration of focal storks. Activity patterns and foraging behaviors of storks feeding in the tidal site are discussed relative to those of storks in non-tidal sites. Results are presented as means ± SD.

RESULTS

We observed the foraging behaviors of 37 Wood Storks (n = 33 adult, 3 subadult, 1 hatch-year) at the tidal site (n = 523 min total observation time) and 34 Wood Storks (n = 14 adult, 8 subadult, 12 hatch-year) at the non-tidal site (n = 2,987 min total observation time). There were no significant differences in foraging success rates between adult and immature storks at either the tidal ($Z = 1.05$, $P = 0.29$) or the non-tidal ($Z = 0.84$, $P = 0.40$) site; therefore, we pooled the data for adult and immature birds by site. The mean time that focal birds remained and were observable at the tidal site was only 14.1 ± 8.6 min, but was 87.9 ± 73.6 min at the non-tidal site ($Z = 6.39$, $P < 0.001$).

The foraging success rate at the tidal creek site was nearly three prey items captured per min (Table 1). Foraging was by far the most frequent behavior of Wood Storks at the tidal site (Table 1), followed by walking and standing; preening, flying, and aggression combined occupied <5% of the birds' time. Behaviors that potentially enhanced foraging efficiency (i.e., foot stirring and wing flashing) were employed at the tidal site.

The foraging success rate at the non-tidal site (0.10 ± 0.09 prey items/min) was significantly lower than it was at the tidal site (Table 1; $Z = -6.75$, $P < 0.001$). Foraging was also the most frequent activity at the non-tidal site (38% of observation time), with standing and preening being next in importance, together constituting more than half of the birds' activities (Table 1). We did not record observations of foot stirring and wing flashing because documenting these behaviors was not part of the methods used at this site.

DISCUSSION

The tidal creek system appeared to be a temporally prey-rich foraging habitat for coastal Wood Storks, although there are tide-related time constraints on site use, and prey sizes may be smaller than at non-tidal sites. Storks tended to forage in the tidal creek habitat for shorter periods, but their foraging success rate (2.95 prey items/min) was very high

TABLE 1. Comparison of foraging behaviors (mean per min) and activity patterns (mean percent time) of Wood Storks using tidal (Purvis Creek, Georgia; n = 37 birds) and non-tidal (Kathwood foraging ponds, inland South Carolina; n = 34 birds) habitats in 1999.

	Tidal	Non-tidal
Foraging behavior[a]		
Success rate (captures/min)	2.95 ± 2.42 (0.1–9.6)	0.10 ± 0.09 (0.0–0.46)
Foot stirs/min	8.1 (0.1–17.0)	Not recorded[b]
Wing flashes/min	0.2 (0.0–1.5)	Not recorded[b]
Activity[c]		
Foraging	78.6% (13.7–99.7%)	38.1% (0.1–99.3%)
Standing	10.8% (0.0–31.5%)	32.4% (0.0–81.4%)
Walking	7.6% (0.0–27.1%)	7.3% (0.0–75.0%)
Preening	3.1% (0.0–49.7%)	20.9% (0.0–62.9%)
Flying[d]	0.2% (0.0–0.9%)	1.1% (0.0–12.1%)
Aggression	0.1% (0.0–1.6%)	<1%

[a] Mean ± SD (range).
[b] Documenting these behaviors was not part of the methods used at the non-tidal site.
[c] Mean (range).
[d] Flying indicates movement within the observation area (bird visible throughout movement).

relative to that at the non-tidal site (~30× greater), supporting suggestions that tidal creeks near low tide provide excellent foraging habitat for storks (Gaines et al. 1998, Bryan et al. 2002). Similarly, Grey Herons (*Ardea cinerea*) feeding in Asian tidal sites also had a greater prey-catching rate than those feeding in non-tidal sites (Sawara et al. 1990). Saltwater prey, however, are generally smaller than freshwater prey (Bryan and Gariboldi 1998), and storks likely require more of the smaller prey to meet their energetic needs. Foot stirring was very prevalent (8.1/min) at our tidal site compared with foot stirring in freshwater impoundments in a similar study (0.1/min; Walsh 1990), and may be a more effective strategy within turbid, flowing tidal environments (Kahl 1964).

Wood Storks in tidal habitat spent twice the percentage of time foraging as storks in the non-tidal habitat, possibly due to constraints on prey availability due to tidal cycles. There simply may not have been enough time for storks to spend on non-foraging behaviors during the short period of low tide and prey availability at this tidal site. Storks at the non-tidal site apparently were able to forage at a slower pace, given the longer period of prey availability; thus, they were able to spend more time resting and preening.

Environmental variables at the tidal site also may have affected stork presence. Microhabitat differences (e.g., creek-bed contour, depth) among tidal creeks result in suitable depths at different times and for varying durations when the tide is ebbing. Variations in fish abundance and diversity occur daily and seasonally within individual tidal creeks (Cain and Dean 1976, Shenker and Dean 1979, Varnell et al. 1995), which likely affect prey availability in the creek. In addition, the tidal creek site had a narrower field of view than the non-tidal site, and the linearity of the habitat may have limited the length of time focal birds could be kept in view. Finally, disturbances caused some storks to abandon the tidal site. The birds were cognizant of the observer during many of our observations at the tidal site (FCD pers. obs.); on rare occasions, sounds made by the observer within the boat and other boat traffic (from local fishermen) may have resulted in site abandonment by storks.

In conclusion, tidal creeks are important, prey-rich foraging habitats for Wood Storks. Tidal systems are more dynamic than non-tidal systems, with storks having higher foraging efficiencies but shorter periods of prey availability. Storks can move to different tidal creeks within the marsh system, but with associated costs (e.g., travel). In the non-tidal system, capture rates of prey are far lower, but prey items are available for longer periods and are likely larger. It is not known whether the overall mass of prey consumed by individual storks differs between tidal and non-tidal foraging habitats. Additional studies of foraging strategies employed by birds using salt marshes (e.g., number of creeks used, total daily foraging time and associated travel time) are needed to determine whether overall consumption rates are similar for the tidal and non-tidal habitats. Regardless, salt marshes are important coastal foraging habitats for postbreeding Wood Storks and should be protected to aid stork recovery.

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